IN THE CLAIMS:

Please amend Claims 1 to 11, and add new Claims 12 to 22 as follows.

1. (Currently Amended) A control apparatus for a vibration type actuator, which makes driving vibration at a driving unit of a vibration member by applying an alternating signal to an electro-mechanical energy conversion element and uses at least a frequency of the alternating signal as a speed control parameter, said control apparatus comprising:

a driving circuit capable of changing a driving voltage of the alternating signal to be applied to said electro-mechanical energy conversion element; and

a control circuit which controls said driving circuit so that at least an absolute value of a slope ~~tilt~~ of a frequency-speed characteristic of said actuator is within a desired range in a frequency band of predetermined range.

2. (Currently Amended) A control apparatus for a vibration type actuator, which makes driving vibration at a driving unit of a vibration member by applying an alternating signal to an electro-mechanical energy conversion element and uses at least a frequency of the alternating signal as a speed control parameter, said control apparatus comprising:

a driving circuit capable of changing a driving voltage of the alternating signal to be applied to said electro-mechanical energy conversion element; and

a control circuit which controls said driving circuit so that an absolute value of a slope ~~tilt~~ of a frequency-speed characteristic of said actuator is equal to or greater than a predetermined value ~~or more~~ at least in a frequency band of predetermined range.

3. (Currently Amended) An apparatus according to Claim 1, wherein said control circuit sets a change rate of the driving voltage relative to the frequency.

4. (Currently Amended) An apparatus according to Claim 2, wherein said control circuit sets a change rate of the driving voltage relative to the frequency.

5. (Currently Amended) An apparatus according to Claim 1, wherein said driving circuit includes a switching circuit which performs on and off operations in response to a driving pulse and applies a voltage according to the switching operation of said switching circuit to said electro-mechanical energy conversion element, and said control circuit changes the width of the driving pulse according to the frequency so that the absolute value of the slope ~~tilt~~ of the frequency-speed characteristic of said actuator is within the predetermined range.

6. (Currently Amended) An apparatus according to Claim 2, wherein said driving circuit includes a switching circuit which performs on and off operations in response to a driving pulse and applies a voltage according to the switching operation of said switching circuit to said electro-mechanical energy conversion element, and said control circuit changes the width of the driving pulse according to the frequency so that the absolute value of the slope ~~tilt~~ of the frequency-speed characteristic of said actuator is equal to or greater than the predetermined value ~~or more~~.

7. (Currently Amended) An apparatus according to Claim 1, further comprising a detection circuit which detects a speed and/or a position of said vibration type actuator, wherein said control circuit changes the driving voltage on the basis of detection information from said detection circuit if said actuator reaches a predetermined position or a predetermined movement amount.

8. (Currently Amended) A control apparatus for a vibration type actuator, which makes driving vibration at a driving unit of a vibration member by

applying an alternating signal to an electro-mechanical energy conversion element and controls at least a frequency of an alternating signal as a speed control parameter, said <u>control</u> apparatus comprising:

a driving circuit capable of changing a driving voltage of the alternating signal to be applied to said electro-mechanical energy conversion element; and

a control circuit for at least performing control in a frequency range higher than a predetermined frequency so that the driving voltage to be applied to said electro-mechanical energy conversion element by said driving circuit decreases as the predetermined frequency becomes a higher frequency.

9. (Currently Amended) An apparatus according to Claim 8, wherein said control circuit decreases the driving voltage to be applied to said electro-mechanical energy conversion element as the predetermined frequency becomes a higher frequency so that an absolute value of a <u>slope</u> ~~tilt~~ of a frequency-speed characteristic in <u>the</u> case of changing a frequency of said actuator by a unit amount is within a predetermined range or is <u>equal to or greater than</u> a predetermined value ~~or more~~.

10. (Currently Amended) An apparatus according to Claim 8, wherein the driving voltage is changed by changing a driving pulse width in said driving circuit <u>for</u> ~~of~~ applying the driving voltage to said electro-mechanical energy conversion element.

11. (Currently Amended) An apparatus according to Claim 8, wherein the driving voltage is changed by changing a gain of an amplifier in said driving circuit <u>for</u> ~~of~~ applying the driving voltage to said electro-mechanical energy conversion element.

12. (New) A control method for a vibration type actuator which makes driving vibration at a driving unit of a vibration member by applying an alternating signal

to an electro-mechanical energy conversion element and uses at least a frequency of the alternating signal as a speed control parameter, said control method comprising the steps of:

changing a driving voltage of the alternating signal to be applied by a driving circuit to the electro-mechanical energy conversion element; and

controlling the driving circuit so that at least an absolute value of a slope of a frequency-speed characteristic of the actuator is within a desired range in a frequency band of predetermined range.

13. (New) A control method for a vibration type actuator which makes driving vibration at a driving unit of a vibration member by applying an alternating signal to an electro-mechanical energy conversion element and uses at least a frequency of the alternating signal as a speed control parameter, said control method comprising the steps of:

changing a driving voltage of the alternating signal to be applied by a driving circuit to the electro-mechanical energy conversion element; and

controlling the driving circuit so that an absolute value of a slope of a frequency-speed characteristic of the actuator is equal to or greater than a predetermined value at least in a frequency band of predetermined range.

14. (New) A control method according to Claim 12, wherein said controlling step includes setting a change rate of the driving voltage relative to the frequency.

15. (New) An control method according to Claim 13, wherein said controlling step includes setting a change rate of the driving voltage relative to the frequency.

16. (New) A control method according to Claim 12, wherein said changing step includes performing on and off operations of a switching circuit in response to a driving pulse and applying a voltage according to the on and off switching operation to the electro-mechanical energy conversion element, and said controlling step includes changing the width of the driving pulse according to the frequency so that the absolute value of the slope of the frequency-speed characteristic of the actuator is within the predetermined range.

17. (New) A control method according to Claim 13, wherein said changing step includes performing on and off operations of a switching circuit in response to a driving pulse and applying a voltage according to the on and off switching operation to the electro-mechanical energy conversion element, and said controlling step includes changing the width of the driving pulse according to the frequency so that the absolute value of the slope of the frequency-speed characteristic of the actuator is equal to or greater than the predetermined value.

18. (New) A control method according to Claim 12, further comprising the step of detecting a speed and/or a position of the vibration type actuator, wherein said controlling step includes changing the driving voltage on the basis of detection information from said detecting step if the actuator reaches a predetermined position or a predetermined movement amount.

19. (New) A control method for a vibration type actuator which makes driving vibration at a driving unit of a vibration member by applying an alternating signal

to an electro-mechanical energy conversion element and controls at least a frequency of an alternating signal as a speed control parameter, said control method comprising the steps of:

changing a driving voltage of the alternating signal to be applied by a driving circuit to the electro-mechanical energy conversion element; and

at least performing control in a frequency range higher than a predetermined frequency so that the driving voltage to be applied to the electro-mechanical energy conversion element by the driving circuit decreases as the predetermined frequency becomes a higher frequency.

20. (New) A control method according to Claim 19, wherein said controlling step includes decreasing the driving voltage to be applied to the electro-mechanical energy conversion element as the predetermined frequency becomes a higher frequency so that an absolute value of a slope of a frequency-speed characteristic in the case of changing a frequency of the actuator by a unit amount is within a predetermined range or is equal to or greater than a predetermined value.

21. (New) A control method according to Claim 19, wherein said changing step includes changing the driving voltage by changing a driving pulse width in a driving circuit for applying the driving voltage to the electro-mechanical energy conversion element.

22. (New) A control method according to Claim 19, wherein said changing step includes changing the driving voltage by changing a gain of an amplifier in said driving circuit for applying the driving voltage to said electro-mechanical energy conversion element.

REMARKS

The claims now pending in the application are Claims 1 to 22, the independent claims being Claims 1, 2, 8, 12, 13 and 19. Claims 1 to 11 have been amended herein. Claims 1 to 22 are newly presented herein.

In the Official Action dated May 30, 2003, Claims 1 to 4, 6 to 8, 10 and 11 were rejected under 35 U.S.C. § 102(a), as anticipated by U.S. Patent No. 6,313,564 (Kataoka). Reconsideration and withdrawal of the rejection respectfully are requested in view of the above amendments and the following remarks.

Initially, Applicant gratefully acknowledges the Examiner's indication that the application contains allowable subject matter, and that Claims 5 and 9 are allowable over the prior art.

In formal matters, by separate paper filed concurrently herewith, Applicant has submitted a Substitute Specification. In the Substitute Specification, the written disclosure and the abstract of the disclosure have been amended as to matters of form, including English spelling, grammar, idiom, syntax and the like. In particular, the term 'slope' has been substituted for the term 'tilt', consistent with common English/US usage in applied mathematics and graphic illustrations of mathematical relationships. No new matter has been added.

Claims 1 to 11 similarly have been amended herein as to matters of form, including English spelling, grammar, idiom, syntax and the like. No new matter has been added.

Newly presented Claims 12 to 22 recite features that parallel the features of prior pending Claims 1 to 11 in method format, and have been added to provide Applicant with an additional scope of protection commensurate with the disclosure. No new matter has been added.

The rejection of the claims over the cited art respectfully is traversed. The present invention relates to a novel control apparatus and method for a vibration type

an alternating signal to an electro-mechanical energy conversion element and uses at least a frequency of the alternating signal as a speed control parameter.

In one aspect, as recited in independent Claim 1, the control apparatus comprises a driving circuit capable of changing a driving voltage of the alternating signal to be applied to the electro-mechanical energy conversion element, and a control circuit which controls the driving circuit so that at least an absolute value of a slope of a frequency-speed characteristic of the actuator is within the desired range in a frequency band of predetermined range.

Newly presented independent Claim 12 recites parallel features with respect to a control method.

In another aspect, as recited in independent Claim 2, the control apparatus comprises such a driving circuit and a control circuit which controls the driving circuit so that an absolute value of a slope of a frequency-speed characteristic of the actuator is equal to or greater than a predetermined value at least in a frequency band of predetermined range.

Newly presented independent Claim 13 recites parallel features with respect to a control method.

In another aspect, as recited in independent Claim 8, the control apparatus comprises such a driving circuit and a control circuit for at least performing control at a frequency range higher than a predetermined frequency so that the driving voltage to be applied to the electro-mechanical energy conversion element by the driving circuit decreases as the predetermined frequency becomes a higher frequency.

Newly presented independent Claim 19 recites parallel features with respect to a control method.

Applicant submits that the prior art fails to anticipate the present invention. Moreover, Applicant submits that there are differences between the subject matter sought to be patented and the prior art, such that the subject matter taken as a whole would not have been obvious to one of ordinary skill in the art at the time the invention was made.

The Kataoka '564 patent relates to a driving apparatus for a vibration type actuator apparatus, and discloses a driving apparatus including an evaluating device which evaluates a wear state of a friction surface between a vibration member and a movable member in a vibration type actuator apparatus. The Kataoka '564 patent detects a change of driving speed of the vibration type actuator at the time of setting an alternating signal which is applied to an electro-mechanical energy conversion element of the vibration member to a predetermined frequency, and a change of frequency of the alternating signal which is required for setting the driving speed of the vibration type actuator to a predetermined speed; based on these detections, the Kataoka '564 patent determines a time at which a friction portion of the vibration member should be replaced. The Kataoka '564 patent illustrates a frequency-speed performance characteristic of the vibration type actuator according to a relative amount of abrasion. However, Applicant submits that the Kataoka '564 patent fails to disclose or suggest at least the above-described features of the present invention. Specifically, Applicant submits the Kataoka '564 patent fails to disclose or suggest an apparatus or method for controlling the slope of the frequency-speed performance characteristic. Thus, the Kataoka '564 patent fails to disclose or suggest an apparatus or method for setting a value of the slope of the frequency-speed characteristic so as to be within a predetermined range (Claims 1 and 12), or an apparatus or method for setting the value of the slope of the frequency-speed characteristic to a value greater than or equal to a predetermined value (Claims 2 and 13). Nor is the Kataoka '564 patent understood to disclose or suggest controlling the driving voltage of an alternating signal so as to set an absolute value of the slope of the frequency-speed characteristic within a frequency band of predetermined range (Claims 1 and 12), controlling the driving voltage of the alternating signal so as to set an absolute value of the slope of the frequency-speed characteristic to a value equal to or greater than a predetermined value (Claims 2 and 13), or controlling the voltage of the alternating signal so as to decrease as the predetermined frequency becomes a higher frequency (Claims 8 and 19), as disclosed and claimed in the present application.

For the above reasons, Applicant submits that independent Claims 1, 2, 8, 12, 13 and 19 are allowable over the cited art.

Claims 3 to 7, 9 to 11, 14 to 18 and 20 to 22 depend from Claims 1, 2, 8, 12, 13 and 19, respectively, and are believed allowable for the same reasons. Moreover, each of these dependent claims recites additional features in combination with the features of its respective base claim, and is believed allowable in its own right. Individual consideration of the dependent claims respectfully is requested.

Applicant believes that the present Amendment is responsive to each of the points raised by the Examiner in the Official Action, and submits that the application is in allowable form. Favorable consideration of the claims and passage to issue of the present application at the Examiner's earliest convenience earnestly are solicited.

Applicant's undersigned attorney may be reached in our Washington, D.C. office by telephone at (202) 530-1010. All correspondence should continue to be directed to our below listed address.

Respectfully submitted,

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(Substitute Specification of U.S. Patent Appln. No. 10/022,338)
(Marked-up Version)

TITLE

CONTROL APPARATUS FOR VIBRATION TYPE ACTUATOR

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION AND RELATED ART

The present invention relates to a control apparatus for a vibration type actuator, ~~actuator~~ such as a vibration wave motor or the like.

Related Background Art

Generally, a vibration type actuator, ~~actuator~~ such as a vibration wave motor or the like, includes a vibration member for making driving vibration and a contact member for press contacting ~~coming into contact with~~ the vibration member, whereby the driving vibration ~~in pressurization, and~~ causes the vibration member and the contact member to ~~relatively~~ move relative to one another ~~by the driving vibration~~.

The ~~Then, the~~ vibration member generally consists of an elastic member and a piezoelectric element functioning as an electro-mechanical energy conversion element. For example, the piezoelectric element may be ~~is~~ disposed so as to have ~~the~~ driving phases ~~phase~~ at positions ~~the position~~ having spatially a mutual phase difference of 90° for each ~~the~~ driving phase of the elastic member, wherein alternating signals of two phases having a mutual phase difference of 90° are applied to these two driving phases to generate a travelling wave on the elastic

member, and the contact member is press-contacted ~~pressure-contacted~~ with the elastic member, thereby obtaining a frictional driving force therebetween ~~frictionally~~.

A frictional ~~Here, it should be noted that a frictional~~ material for obtaining the appropriate frictional force is adhered, coated or formed at the contact portion between the vibration member and the contact member.

When ~~With respect to the features of the vibration type actuator, as~~ compared with an actuator using electromagnetic force, the ~~several points that~~ driving torque of a vibration type actuator at low speed is large, responsiveness is excellent, and it is silent because a vibration above the human ~~, as the vibration over an~~ audible range is used, so humans do not sense ~~can not feel~~ any driving sound is generated ~~are enumerated~~. Therefore, the vibration type actuator is suitably used as, e.g., the driving unit of an image formation apparatus.

Generally, since a large voltage is necessary for a vibration ~~the vibration~~ type actuator, the voltage is boosted or raised ~~risen~~ by one method or a combination of plural methods. For example, a driving signal may be ~~is~~ amplified by a linear amplifier, the voltage may be ~~is~~ boosted by a transformer, or an inductance element and a switching element may be ~~are~~ combined such that ~~and thus~~ a resonance with the capacitance component of the vibration type actuator may be ~~is~~ used.

In these methods described above, either the method of boosting the voltage using a ~~by the~~ transformer or the method of boosting the voltage using a combination of an ~~by combining the~~ inductance element and a ~~the~~ switching

element is desirably used because each ~~it~~ is excellent in respects of efficiency, costs and the like.

Moreover, as methods of controlling the driving speed of the vibration type actuator, there are a method of controlling the driving speed ~~by~~ using a driving voltage, a method of controlling the driving speed ~~by~~ using a driving frequency, and a method of controlling the driving speed ~~by~~ using a phase between adjacent driving phases. Of ~~In~~ these methods, the method of controlling the driving speed ~~by~~ using the driving frequency is desirably used because it can achieve both a wide dynamic range and high resolution alone, ~~singly~~ and is excellent when used ~~in conformity~~ with a recently developed digital circuit.

However, in the driving speed control method using the driving frequency, as shown in Fig. 4, a frequency-speed characteristic changes greatly according to the ~~a~~ frequency, whereby there is a problem in that a change rate of the speed varies even at the same control operation amount.

Particularly, if the driving frequency is displaced ~~apart~~ from a resonance frequency (fr), a slope ~~tilt~~ (i.e., the slope ~~tilt~~ of the frequency curve for the speed) decreases, whereby there is a problem in that a necessary control gain can not be obtained and the speed does not decrease.

That is, there is a problem that controllability deteriorates in a low-speed range. Further, ~~Besides,~~ if the control gain is set at low speed, there is a problem in that oscillation occurs in high-speed driving. Particularly, when the vibration type actuator is used in positioning control, there is a problem in that a desired device can not be accurately stopped at a desired position.

SUMMARY OF THE INVENTION

An object of the present invention is to provide a control apparatus, for a vibration type actuator, which achieves steady driving by a simple manner in a wide range of the driving from high speed to low speed.

In one aspect, ~~One aspect of~~ the present invention relates ~~is~~ to ~~provide~~ a control apparatus and method for a vibration type actuator which ~~, which~~ makes driving vibration at a driving unit of a vibration member by applying an alternating signal to an electro-mechanical energy conversion element and uses at least a frequency of the alternating signal as a speed control parameter, where the apparatus comprises: ~~comprising:~~ a driving circuit capable of changing a driving voltage of the alternating signal to be applied to the electro-mechanical energy conversion element; and a control circuit for controlling the driving circuit so that at least an absolute value of a slope ~~tilt~~ of a frequency-speed characteristic of the actuator is within a predetermined range in a frequency band of predetermined range.

In another aspect, ~~One aspect of~~ the present invention relates ~~is~~ to ~~provide~~ a control apparatus and method for a vibration type actuator which ~~, which~~ makes driving vibration at a driving unit of a vibration member by applying an alternating signal to an electro-mechanical energy conversion element and uses at least a frequency of the alternating signal as a speed control parameter, where the apparatus comprises: ~~comprising:~~ a driving circuit capable of changing a driving voltage of the alternating signal to be applied to the electro-mechanical energy conversion element; and a control circuit for controlling the driving circuit so that an absolute value of a slope ~~tilt~~ of a frequency-speed characteristic of the actuator

is a predetermined value or greater ~~more~~ at least in a frequency band of predetermined range.

In another aspect, ~~One aspect of~~ the present invention relates ~~is~~ to ~~provide~~ a control apparatus and method for a vibration type actuator which ~~, which~~ makes driving vibration at a driving unit of a vibration member by applying an alternating signal to an electro-mechanical energy conversion element and controls at least a frequency of an alternating signal as a speed control parameter, where the apparatus comprises: ~~comprising:~~ a driving circuit capable of changing a driving voltage of the alternating signal to be applied to the electro-mechanical energy conversion element; and a control circuit for at least performing control in a frequency range higher than a predetermined frequency so that the driving voltage to be applied to the electro-mechanical energy conversion element by the driving circuit decreases as the predetermined frequency becomes a higher frequency.

Other objects of the invention will become apparent from the following embodiments which will be explained with reference to the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram showing a first ~~the first~~ embodiment of the present invention;

Fig. 2 is a cross-sectional view showing the structure of an example of a vibration type actuator in the present invention;

Fig. 3 is a block diagram showing a conventional control apparatus corresponding to the present invention;

Fig. 4 is a view showing a frequency-speed characteristic of the vibration type actuator in the present invention;

Fig. 5 is a view showing an example of a speed command in position control;

Fig. 6 is a view showing the frequency-speed characteristics of the vibration type actuator, in the first embodiment of the present invention and a conventional control circuit;

Fig. 7 is a view showing the frequency-speed characteristics of the vibration type actuator, in a the modification of the first embodiment and the conventional control circuit;

Fig. 8 is a block diagram showing a second ~~the second~~ embodiment of the present invention;

Fig. 9 is a block diagram showing a third ~~the third~~ embodiment of the present invention;

Fig. 10 is a block diagram showing a fourth ~~the fourth~~ embodiment of the present invention;

Fig. 11 is a view showing pulses for driving a MOSFET in a conventional example;

Fig. 12 is a view showing a state in which ~~that~~ pulses for driving a MOSFET are squeezed (compacted) in the present invention;

Fig. 13 is a view showing the frequency-speed characteristic of the vibration type actuator in the first embodiment of the present invention;

Fig. 14 is a block diagram showing a fifth ~~the fifth~~ embodiment of the present invention; and

Fig. 15 is a view showing an operation in the fifth embodiment.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

(First Embodiment)

Fig. 1 is a block diagram showing a first ~~the first~~ embodiment of the present invention, Fig. 2 is a cross-sectional view showing an example of a vibration type actuator which can effectively implement ~~perform~~ the present invention, and Fig. 3 is a block diagram showing a conventional positioning circuit corresponding to the circuit shown in Fig. 1.

In the vibration type actuator shown in Fig. 2, both sides of a laminated piezoelectric element 17, ~~17~~ which has plural sets of two driving phases disposed at positions having spatially a mutual phase difference of 90°, ~~90°~~ are disposed (sandwiched) ~~put~~ and supported between elastic members 16 and 18. By applying alternating signals of two phases having a mutual phase difference of 90° to the two driving phases of the piezoelectric element 17, travelling waves as driving vibrations are generated on the outer surfaces of the respective elastic members 16 and 18, and rotation members 15 and 19, ~~19~~ functioning as contact members, ~~members~~ are press-contacted ~~pressure-contacted~~ with the elastic members 16 and 18, ~~18~~ respectively, thereby obtaining a frictional driving force therebetween ~~based on frictional force~~. Here, for example, plural ranges respectively having different polarization directions are provided in each driving phase. Thus, for one driving phase, displacements of expansion and shrinking are simultaneously given in the thickness direction (axial direction) by applying ~~the~~ sine-wave alternating signals to the ranges of the different polarization directions, whereby bending vibration is

made. Similarly, for the other driving phase, a bending ~~the bending~~ vibration is made by applying ~~the~~ cosine-wave alternating signals. Moreover, in a case where the polarization ranges of the respective driving phases are turned to the same polarization direction, ~~the~~ phase-inverted alternating signals are applied.

When the actuator is driven, pulses having arbitrary pulse widths and frequencies and having a mutual phase difference of 180° are applied to the gates of MOSFET's (metal oxide semiconductor field-effect transistors) 7 and 8 for ~~the~~ one driving phase connected to a coil 11 and to the gates of MOSFET's 9 and 10 for the other driving phase connected to a coil 12.

That is, the switching pulse is set to have the phases 0°, 180°, 90° and 270° in due order from g1 to g4, ~~g4~~ with a pulse ~~the pulse~~ width of approximately 50%, as shown in Fig. 11. When the pulse is inverted, it is set to have the phases 0°, 180°, -90° and -270° in due order from g1 to g4. The value of the coil is set to match the capacitance of the vibration type actuator. Actually, the resonance frequencies of the coil and the capacitance are set to be higher than the resonance frequency of the actuator so as to moderate a change rate of a voltage.

Fig. 3 shows an example of a conventional ~~the conventional~~ positioning control circuit. In the control circuit of a conventional vibration type actuator 13, a speed signal v of ~~of a~~ speed detection means 14, ~~14~~ such as a known rotary encoder or the like for detecting ~~the~~ rotation of the vibration type actuator 13, is ~~13 is~~ converted into a position signal P by a position counter 5. Then, a speed command Vc according to the current position is generated by a position control block 2 so as to reach the target position, e.g., as shown in Fig. 5. Further, a frequency f of the pulse for driving ~~to drive~~ the vibration type actuator is determined based on the

speed command Vc, the speed signal V from the speed detection means 14, a control gain and the like by a speed control block 3, and the determined frequency f is output to a pulse generator 6.

A pulse width PW of a pulse generated by the pulse generator 6 is set to have a predetermined value irrespective of the command frequency f.

The pulses of four phases are generated based on the command frequency f and the pulse width PW by the pulse generator 6 to drive MOSFET's 7 to 10, whereby the vibration type actuator 13 is driven through coils 11 and 12.

Since the vibration type actuator 13 has the frequency-speed characteristic (i.e., the speed characteristic for the change in a unit amount of the frequency) as shown in Fig. 4, the speed can be controlled by adjusting the frequency. However, since the <u>slope</u> ~~tilt~~ of the frequency-speed characteristic changes greatly according to the frequency, there is a fear that satisfactory control can not be performed according to the speed range. Particularly, the gain does not suffice in low speed. In ~~the~~ positioning control, to improve the stop accuracy and decrease an impulsive sound at the time of start and stop, ~~the~~ speed control as shown in Fig. 5 is performed. In this case, it is necessary to perform ~~the~~ steady speed control within a wide speed range. Particularly, ~~the~~ stability in the low-speed range is important. Moreover, since the speed does not decrease <u>sufficiently</u> ~~enough~~ in a predetermined frequency range, there is a fear that it <u>may cause</u> ~~causes~~ an overrun.

On the other hand, in the first embodiment of the <u>present</u> invention, as shown in Fig. 1, a pulse width PW corresponding to a frequency command f generated by a speed control block 3 is stored beforehand in a known memory

device 4, ~~4~~ such as a RAM, a ROM or a gate array, and thus the pulse width PW according to the frequency command f is output to the ~~to a~~ pulse generator 6.

A table for the frequency commands f and the pulse widths PW is set beforehand by experiment or study so that the absolute value of the slope ~~tilt~~ of the frequency-speed characteristic can secure a gain sufficient ~~enough~~ for ~~the~~ control or can be set in a predetermined range. Fig. 6 shows the frequency-speed characteristics in the conventional art and the first embodiment.

In the first embodiment, the pulse width for the frequency is determined so that the frequency-speed characteristic almost becomes a straight line. That is, the pulse width is maximum at a point "a" ~~a~~ (frequency fa), and the pulse width is squeezed (compressed) at points ~~the~~ above and below ~~of the~~ point a (above and below ~~of~~ frequency fa). Fig. 12 shows the state in which ~~that~~ the pulses are squeezed (compressed) but having ~~with~~ the same frequency ~~same~~ as that in Fig. 11. As a result, since the response to the control command becomes the same at any frequency, a steady ~~the steady~~ control can be performed in a wide ~~the wide~~ speed range from high speed to low speed, whereby it is suitable for ~~the~~ positioning control.

Incidentally, it is difficult to make the frequency-speed characteristic linear accurately and completely. However, as shown in Fig. 13, there is no problem even if a range of the slope ~~tilt~~ of the frequency-speed characteristic is determined and the slope ~~tilt~~ is made to be put within this range.

Further, ~~Besides,~~ if the necessary gain only has to be secured, it is also effective to set the absolute value of the slope ~~tilt~~ of the frequency-speed characteristic of the vibration type actuator to be a predetermined value or greater,

~~more~~ as shown in Fig. 7. In this case, the pulse width is squeezed (compressed) at the frequency above a point "a" ~~point a~~ (frequency fa). Although the frequency-speed characteristic does not become linear entirely in the used frequency range, ~~the~~ control can be performed in a wide ~~the wide~~ speed range because the necessary control gain can be secured. In this case, ~~the~~ control becomes possible even as for farther higher speed ~~farther~~. Although an ~~the~~ apparatus for positioning control has been described ~~was explained~~ in the first embodiment, the same effect as above can be obtained if the embodiment is applied to an apparatus only for speed control.

(Second Embodiment)

Fig. 8 shows a second ~~the second~~ embodiment of the present invention.

It should be noted that, in the second embodiment, the explanation of the same parts as those in the first embodiment will be omitted. According to the second embodiment, in a speed control block 3 which consists of a logic circuit, ~~circuit~~ such as a known CPU, a gate array or the like, a reduction number $\Delta PW(f)$ of the pulse width is calculated from a command frequency f, and thus a command pulse width PW is determined.

For example, the reduction number of the pulse width can be calculated from the frequency fa at the point "a" of ~~a of~~ Fig. 6 and the command frequency f by using an equation $\Delta PW(f) = k|f\text{-}fa|$. Here, the value of k which is a constant is set so that the slope ~~tilt~~ of the frequency-speed characteristic of the vibration type actuator is set ~~put~~ within an almost-constant predetermined range. In the second embodiment, a memory ~~any memory~~ element is not necessary; ~~necessary, and~~ its function ~~substitute~~ can be achieved by using the element shared with another block, ~~block~~ such as the CPU or the gate array.

Incidentally, if the pulse width is decreased only in the case of f > fa, the same effect as that shown in Fig. 7 of the first embodiment can be obtained, whereby ~~the~~ control becomes possible as for higher speed.

Although an ~~the~~ apparatus for positioning control has been described ~~was explained~~ in the second embodiment, the same effect as above can be obtained if the embodiment is applied to an apparatus only for speed control.

(Third Embodiment)

Fig. 9 shows a third ~~the third~~ embodiment of the present invention. It should be noted that, in the third embodiment, the explanation of the same parts as those in the first embodiment will be omitted.

According to the third embodiment, a DC power supply 1 is a controllable power supply which can control a voltage using ~~by~~ a digital signal, a voltage and other means. A memory device 4, which stores a table for a frequency and a voltage value command DCV of the DC power supply, outputs the command voltage DCV to the DC power ~~poser~~ supply 1 in accordance with a command frequency f output from a speed control block 3.

As in ~~well as~~ the first and second embodiments, in order to be able to secure a gain sufficient ~~the gain enough~~ for ~~the~~ control, the third embodiment is set so that the absolute value of the slope ~~tilt~~ of the frequency-speed characteristic of the vibration type actuator is set ~~put~~ within a predetermined range.

That is, the voltage of the DC power supply is decreased at the upper and lower portions of the driving frequency range (high-frequency portion and low-frequency portion within the frequency range used for driving). Therefore, the amplitude in the part where the voltage of the DC power supply was decreased

becomes small, whereby speed decreases. The effect obtained by doing so is the same as the effect in the first embodiment.

Further, if it is to only secure the necessary gain, the voltage of the DC power supply may be decreased at a predetermined frequency, higher than the resonance frequency of the vibration type actuator, or more. Moreover, as in ~~well as~~ the second embodiment, a reduction rate of the voltage of the DC power supply to the frequency may be calculated by the speed control block.

(Fourth Embodiment)

Fig. 10 shows a fourth ~~the fourth~~ embodiment of the present invention. It should be noted that, in the fourth embodiment, the explanation of the same parts as those in the first embodiment will be omitted. In Fig. 10, numeral 15 denotes an oscillator which performs oscillation at a frequency according to a frequency command f output from a speed control block 3, such ~~3 such~~ as a known VCO (voltage-controlled oscillator). Numeral 16 denotes a power amplifier to which a gain command Ga can be set externally. A memory device 4, which stores a table for a frequency and the gain command Ga of the power amplifier 16, outputs the gain command Ga of the power amplifier 16 in accordance with the frequency command f output by the speed control block 3. As in ~~well as~~ the first and second embodiments, in order to be able to secure a gain sufficient ~~the gain enough~~ for ~~the~~ control, the fourth embodiment is arranged so that the absolute value of the slope ~~tilt~~ of the frequency-speed characteristic of the vibration type actuator is set ~~put~~ within a predetermined range.

That is, the gain of the power amplifier 16 is decreased at the upper and lower portions of the driving frequency range. The effect obtained by doing so is the same as the effect in the first embodiment.

Further, if it is to only secure the necessary gain, the gain of the power amplifier 16 may be decreased at a predetermined frequency, higher than the resonance frequency of the vibration type actuator, or more. Moreover, as in ~~well as~~ the second embodiment, a reduction rate of the gain of the power amplifier 16 to the frequency may be calculated by the speed control block.

(Fifth Embodiment)

Fig. 14 is a block diagram showing a fifth ~~the fifth~~ embodiment of the present invention. Here, a timer 24 generates a trigger signal Tg at a constant interval, and an up down counter 25 performs up and down count in accordance with the trigger signal Tg from the timer 24. Further, a position control block 2 generates a speed command Vc, ~~Vc~~ as shown in Fig. 5, and ~~5 and~~ also generates a control state signal SM.

The operation of the up down counter 25 is determined by the value of the control state signal SM. As shown in Fig. 15, at the time of acceleration (SM = 1), the pulse width increases from the initial pulse width whenever the trigger signal Tg is input, while at the time of deceleration (SM = 3, 4), the pulse width decreases whenever the trigger signal Tg is input. Since the frequency-speed characteristic of the vibration type actuator is as shown in Fig. 4, the driving frequency decreases most at constant speed, and, on the other hand, the driving frequency increases at the time of acceleration and deceleration. At this time, a period in which ~~that~~ the timer generates the trigger signal Tg and amounts of increase and decrease of the

pulse width are appropriately set so that the frequency-speed characteristic of the vibration type actuator has a curve the ~~the curve~~ same as the curve shown in Fig. 7. The changes of the frequency and the pulse width at this time are shown in Fig. 15. Also in this case, since the frequency-speed characteristic is corrected so as to become nearly linear, as in ~~well as~~ the first to fourth embodiments, controllability in each speed range becomes steady.

Here, although both the cases of acceleration and deceleration were explained, the above operation alternatively may be performed only at the time of deceleration (SM = 3, 4), ~~4)~~ which is most important for positioning accuracy. Further, it is also effective to perform the above operation only when SM = 3 in some deceleration, ~~deceleration~~ to prevent the stop unanticipated at low speed, and to set a limit value PWmin for the pulse width, ~~width~~ as shown in Fig. 15, so ~~15 so~~ that the pulse generator does not output a pulse ~~the pulse~~ width below the limit value.

In the above description, although the pulse width was explained as a parameter to correct the frequency-speed characteristic of the vibration type actuator, it is, of course, ~~it is~~ also effective to directly modify the applied voltage, the voltage of the DC power supply, the gain of the linear amplifier or the like at a constant period.

ABSTRACT OF THE DISCLOSURE

A control ~~The present invention relates to a control~~ apparatus for a vibration type actuator~~, and particularly to a control apparatus which~~ improves controllability by providing a control circuit that adjusts ~~of adjusting~~ a voltage to be applied to the actuator so that a slope ~~tilt~~ of a frequency-speed characteristic of the actuator becomes approximately a constant slope ~~tilt~~.

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